HUMAN PHYSIOLOGY (normal)

LECTURE 7. Autonomic Nervous System

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Autonomic Nervous System

Autonomic nervous system (ANS) is primarily concerned with regulation of visceral or **vegetative** functions of the body. The “vegetative” functions of the organism are: metabolism, respiration, excretion, fluids circulation

Operates largely outside our awareness (“Autonomic”). The subconscious sensory signals from a visceral organ can enter the autonomic ganglia, the brain stem, or the hypothalamus and then return subconscious reflex *responses* directly back to the visceral organ to control its activities.

Nerve terminals are located in **smooth muscle** (eg, blood vessels, gut wall, urinary bladder), **cardiac muscle**, and **glands** (eg, sweat glands, salivary glands)

Divisions of the ANS

Sympathetic division

- increases alertness, metabolic rate, and muscular abilities

Parasympathetic division

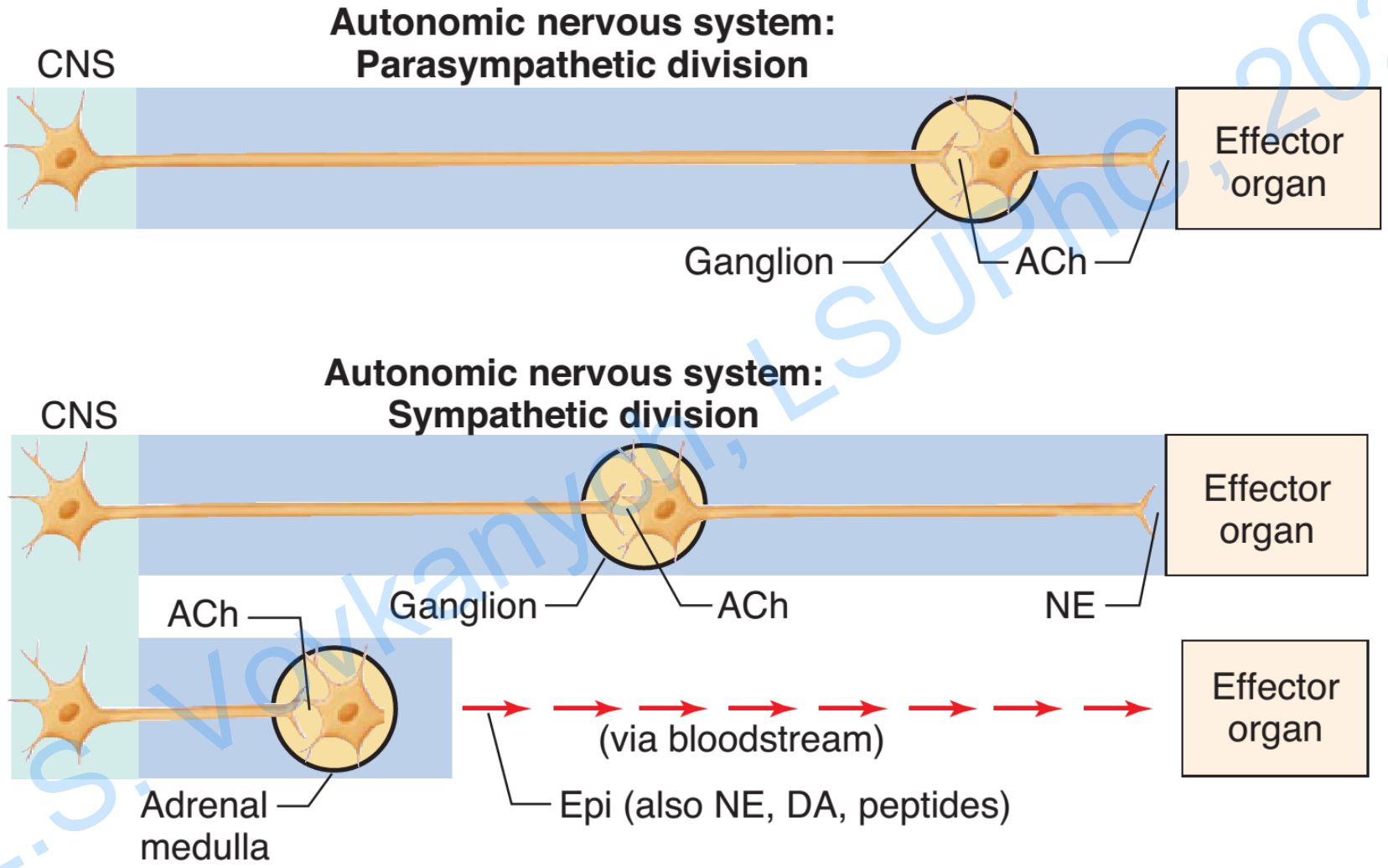
- reduces metabolic rate and promotes digestion

- Some target organs are innervated by **both divisions** and others are controlled by **only one**.

Enteric nervous system

- located within the gastrointestinal tract.

Mediators of the ANS



ACh, acetylcholine;

NE, norepinephrine; Epi, epinephrine; DA, dopamine;

Sympathetic Division

Preganglionic Neurons

- Releases ACh at synapses with ganglionic neurons

Ganglionic Neurons

- Release norepinephrine (NE) at most **varicosities**
- Releasing NE at peripheral **synapses**
- Distributing epinephrine (E) and NE throughout body in bloodstream

There are **two types** of **adrenergic** membrane receptors

- **Alpha** receptors (NE more potent)
- **Beta** receptors (E more potent)

Adrenergic membrane receptors

Receptor	Location(s)	Response(s)	Mechanism
Alpha-1 (α_1)	Widespread, found in most tissues	Excitation, stimulation of metabolism	Enzyme activation; intracellular release of Ca^{2+}
Alpha-2 (α_2)	Sympathetic neuromuscular or neuroglandular junctions	Inhibition of effector cell	Reduction of cAMP concentrations
Beta-1 (β_1)	Heart, kidneys, liver	Stimulation, increased energy consumption	Enzyme activation
Beta-2 (β_2)	Smooth muscle in vessels, intestines, lungs, bronchi	Inhibition, relaxation	Enzyme activation
Beta-3 (β_3)	Adipose tissue	Stimulation of lipolysis	Enzyme activation

Sympathetic release of ACh and NO

Cholinergic (ACh) sympathetic terminals

- Innervate **sweat glands of skin** and **blood vessels** of **skeletal muscles** and **brain**
- **Stimulate sweat gland** secretion and **dilate blood vessels**

Nitroxidergic synapses

- Release **nitric oxide** (NO) as neurotransmitter
- Neurons innervate **smooth muscles** in walls of **blood vessels** in **skeletal muscles** and the **brain**
- Produce **vasodilation** and increased blood flow

Sympathomimetic Drugs

- Produce the effects of sympathetic stimulation.
- Both E and NE act only for a short duration of about 1 to 2 minutes
- Sympathomimetic drugs injected intravenously act for 30 min. - 2 hours

Drugs stimulating the **Receptors Directly**

- Phenylephrine (alpha receptors)
- Isoproterenol (beta receptors)
- Albuterol (beta2 receptors)

Drugs Inducing the **release of NE**

- Ephedrine
- Tyramine
- Amphetamine

Sympathetic Blockers

Drugs that **prevent actions of sympathetic neurotransmitter**

- **Reserpine** (prevention of synthesis and storage of NE)
- **Quanethidine** (prevention of release of NE)
- **Phentolamine** (blockade of alpha adrenergic receptors)
- **Metaprolol** (blockade of beta adrenergic receptors)
- **Hexamethonium** (blockade of transmission of nerve impulse through sympathetic ganglia)

Parasympathetic Division

Preganglionic Neurons

- Releases **Acetylcholine** (ACh) at synapses with ganglionic neurons

Ganglionic Neurons

- Release ACh as neurotransmitter
- ACh is inactivated by acetylcholinesterase (AChEsterase) at synapse

There are **two types** of ACh membrane receptors

- **Nicotinic receptors**
- **Muscarinic receptors**

Membrane Receptors of ACh

Receptor	Location(s)	Response(s)	Mechanism
Nicotinic	All autonomic synapses between preganglionic and ganglionic neurons; neuromuscular synapses of SNS	Stimulation, excitation; muscular contraction	Opening of chemically gated Na^+channels
Muscarinic	All parasympathetic and cholinergic sympathetic neuromuscular or neuroglandular junctions	Variable	Enzyme activation (G proteins) causing changes in membrane permeability to K^+

Parasympathomimetic Drugs

- Produce the effects of parasympathetic stimulation
- Exhibit their actions for a longer time

Drugs which **act on Muscarinic receptors**

- **Pilocarpine**
- **Methacholine**

Drugs which **prolong the action of ACh** (inhibit the activity of acetylcholinesterase)

- **Neostigmine**
- **Physostigmine**

Parasympathetic Blockers

Drugs, which prevent the actions of parasympathetic neurotransmitter (inhibit the actions of ACh by blocking the **muscarinic receptors**)

- **Atropine**
- **Scopolamine**

Ganglionic blockers are the drugs that prevent the transmission of impulses from preganglionic neurons to postganglionic neurons (block both sympathetic and parasympathetic ganglia are commonly used to block sympathetic ganglia)

- **Tetraethyl ammonium** ion
- **Hexamethonium** ion
- **Pentolinium**

Visceral Reflexes

Long reflexes

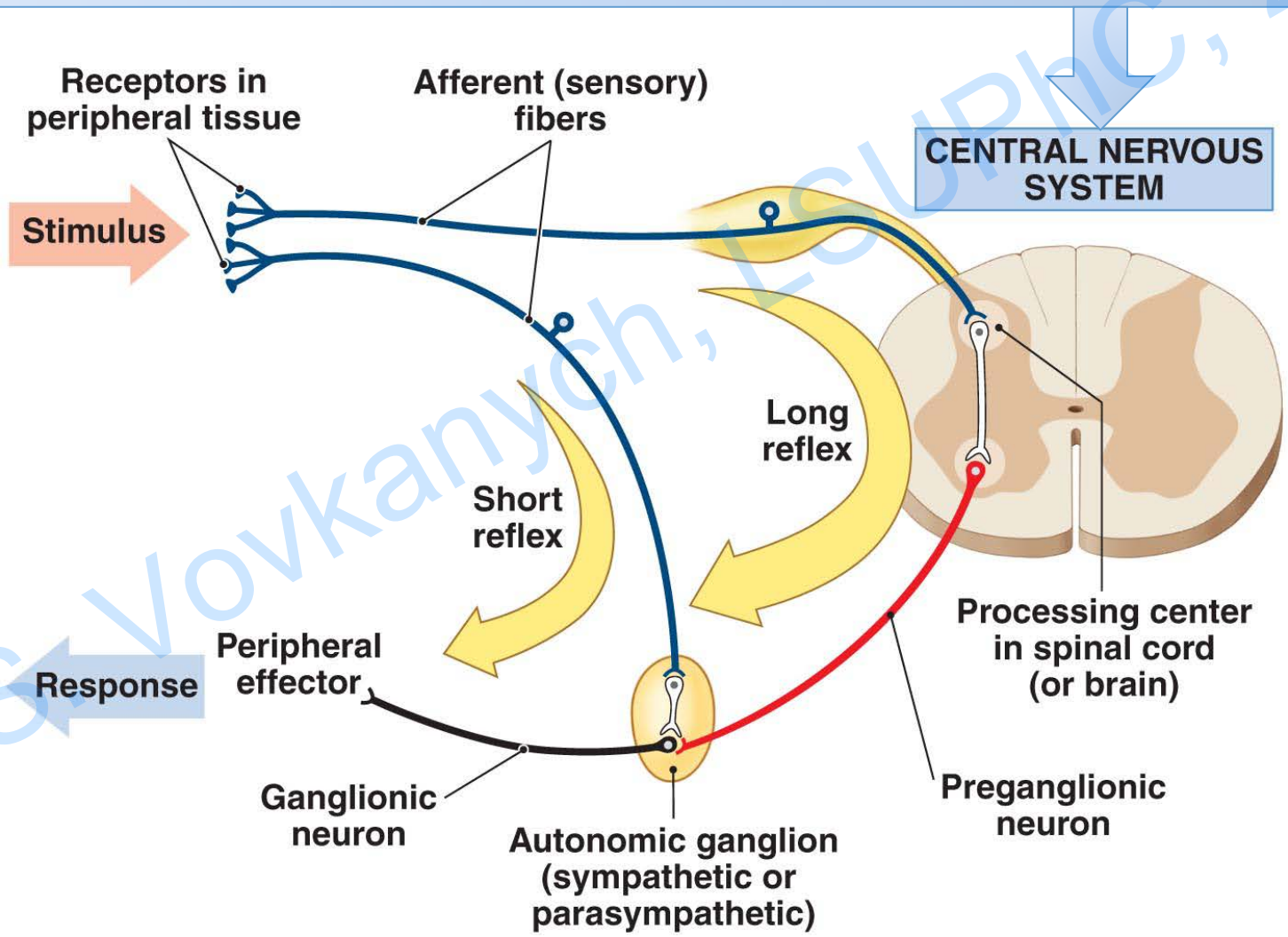
- Visceral sensory neurons deliver information to CNS along dorsal roots of spinal nerves
- ANS carries motor commands to visceral effectors
- Coordinate activities of entire organ, important in most organs

Short reflexes

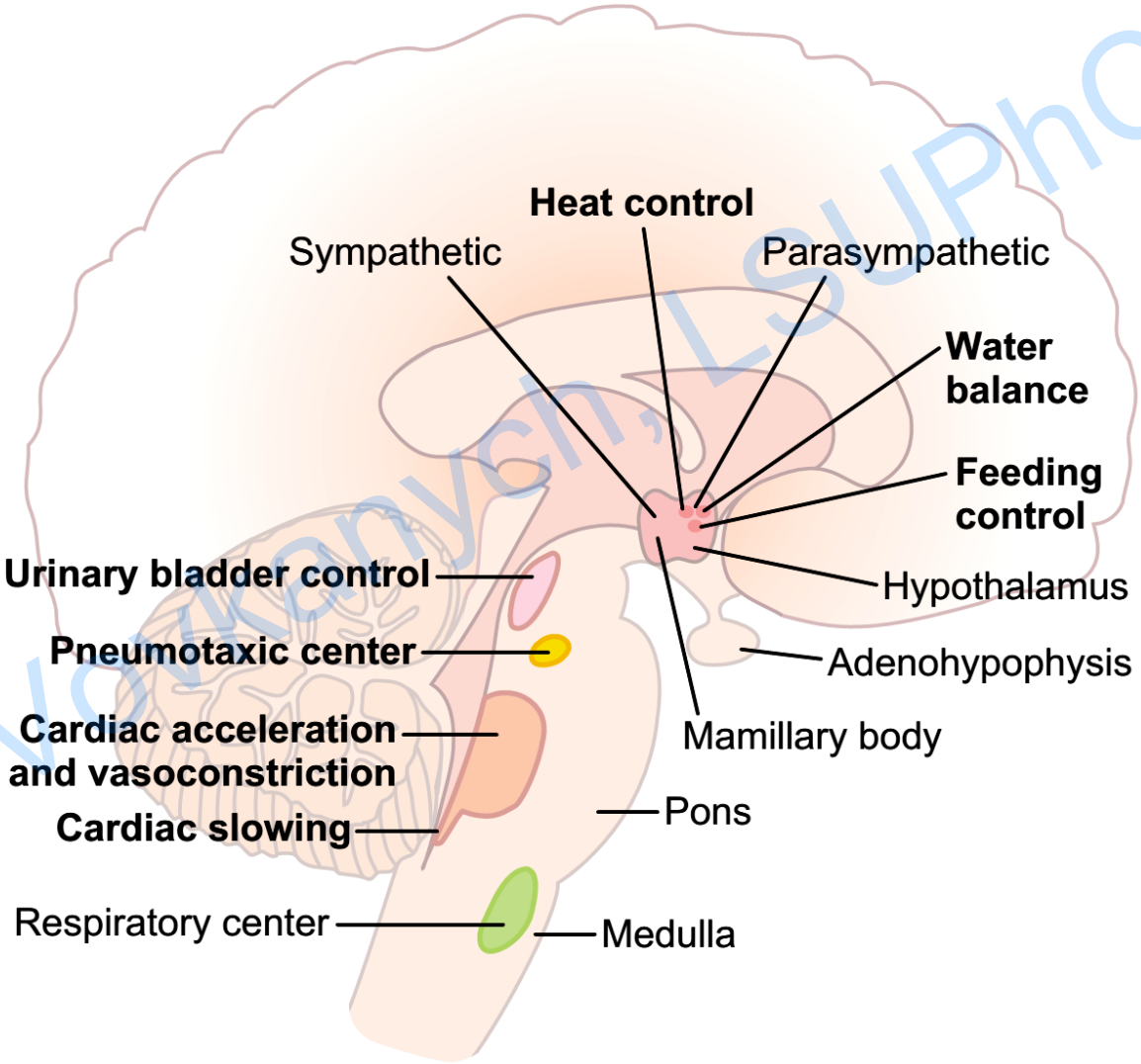
- Bypass CNS, involve sensory neurons and interneurons located within autonomic ganglia
- Control simple motor responses with localized effects
- One small part of target organ, important in Digestive tract

Visceral Reflexes

All visceral reflexes can be modified, **facilitated**, or **inhibited** by higher centers, especially **hypothalamus**



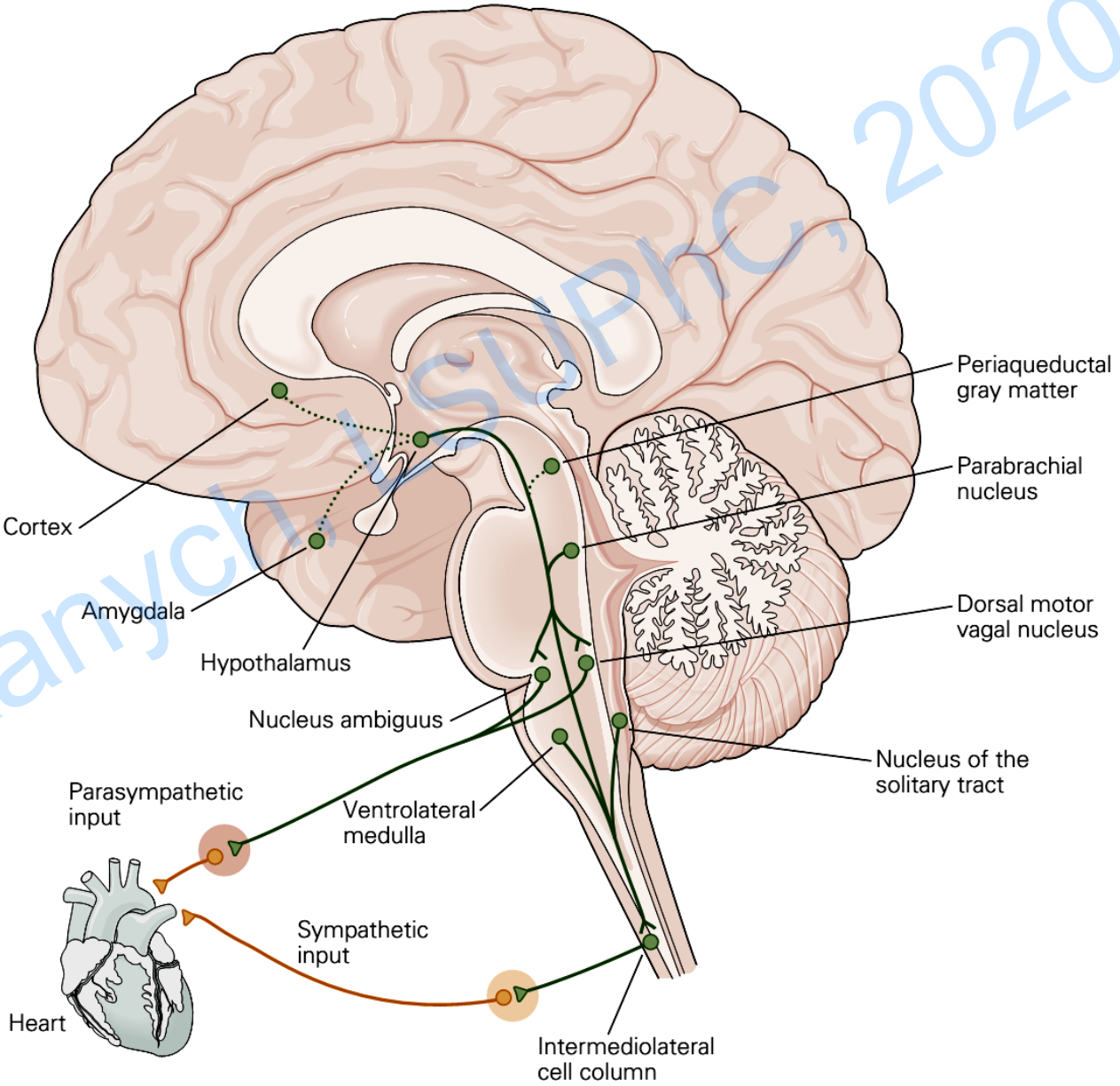
Autonomic control areas in the brain stem and hypothalamus



Control of autonomic responses

Direct projections
(solid lines)
- hypothalamic paraventricular nucleus,
- parabrachial nucleus, nucleus of the solitary tract,
- ventrolateral medulla

Indirect projections
(dashed lines)
- cerebral cortex,
- mygdala,
- periaqueductal grey matter



Visceral Reflexes

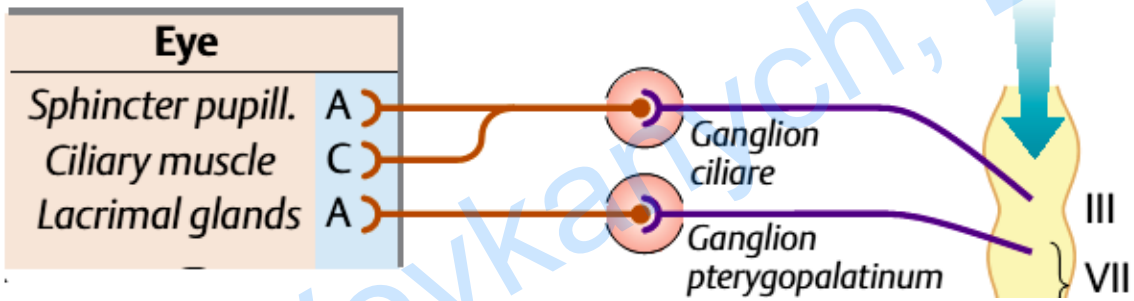
Reflex	Stimulus	Response
Gastric and intestinal reflexes	Pressure and physical contact	Smooth muscle contractions that propel food materials and mix with secretions
Defecation	Distention of rectum	Relaxation of internal anal sphincter
Urination	Distention of urinary bladder	Contraction of walls of urinary bladder; relaxation of internal urethral sphincter
Direct light reflex	Bright light	Constriction of pupils of both eyes
Baroreceptor reflex	Sudden rise in carotid blood pressure	Reduction in heart rate and force of contraction

Visceral Reflexes

Reflex	Stimulus	Response
Cardioacceleratory reflex	Sudden decline in blood pressure in carotid artery	Increase in heart rate and force of contraction
Vasomotor reflexes	Changes in blood pressure in major arteries	Changes in diameter of peripheral vessels
Pupillary reflex	Low light level	Dilation of pupil

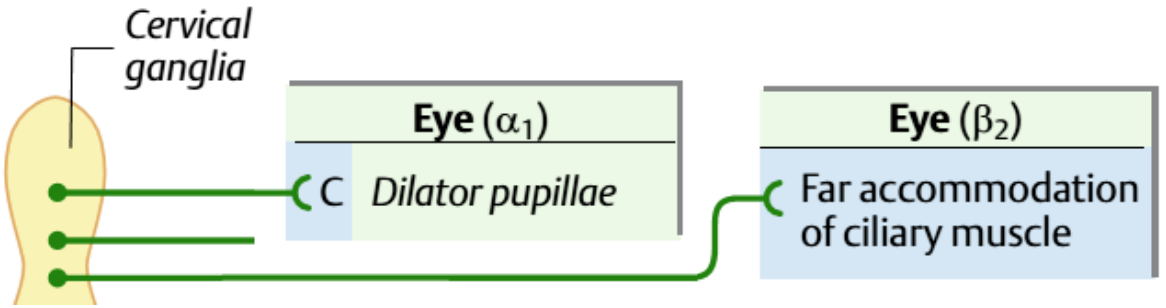
Actions of ANS

Structure	Sympathetic Effects	Parasympathetic Effects (muscarinic)
EYE	Dilation of pupil (α_1); accommodation for distance vision (β_2)	Constriction of pupil for close vision
Lacrimal glands	None (not innervated)	Secretion



Parasympathetic Effects

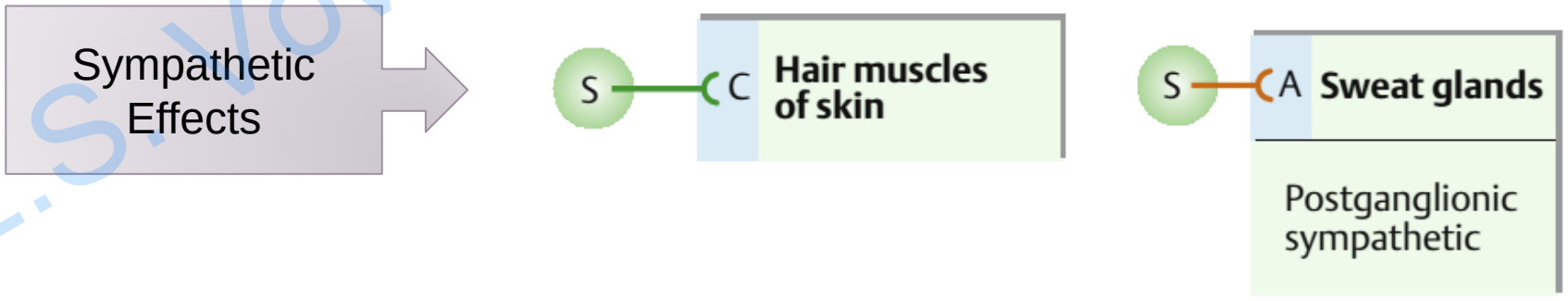
Sympathetic Effects



A = Activation | I = Inhibition | C = Contraction | R = Relaxation | D = Dilatation

Actions of ANS

Structure	Sympathetic Effects	Parasympathetic Effects (muscarinic)
SKIN		
Sweat glands	Increased secretion, palms and soles (α_1); generalized increase in secretion (cholinergic)	None (not innervated)
Errector of **pili muscles**	Contraction; erection of hairs (α_1)	None (not innervated)

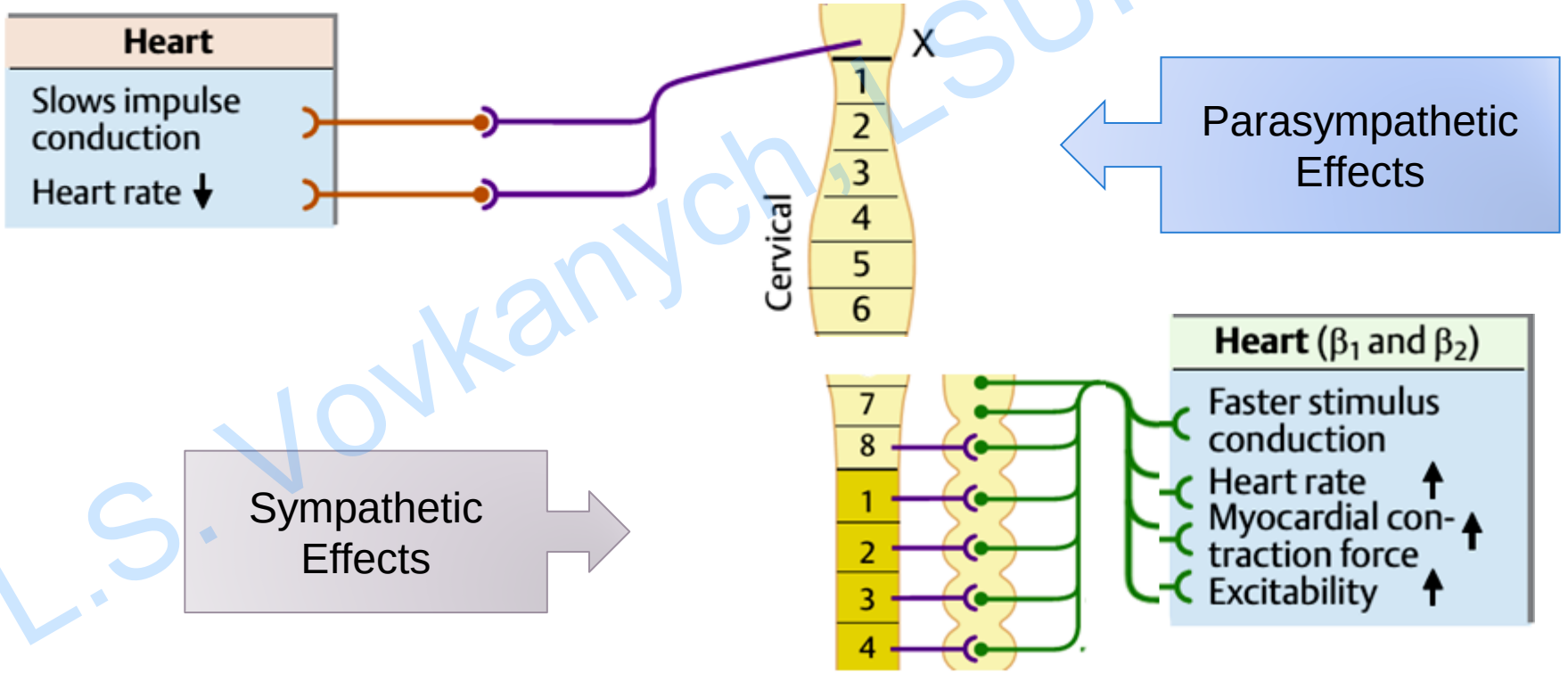


Actions of ANS

Structure	Sympathetic Effects	Parasympathetic Effects
CARDIOVASCULAR SYSTEM		
Arteries of **skin**	Dilation (cholinergic); constriction (α_1)	None
Arteries of **skeletal muscles**	Dilation (β_2 and cholinergic; nitroxidergic)	None
Arteries of **heart**	Dilation (β_2); constriction (α_1, α_2)	None
Arteries of **lungs**	Dilation (β_2); constriction (α_1)	None
Arteries of **digestive viscera**	Constriction (α_1); dilation (α_2)	None
Arteries of **kidneys**	Constriction, decreased urine production (α_1, α_2) dilation, increased urine production (β_1, β_2)	None
Arteries of **brain**	Dilation (cholinergic and nitroxidergic)	None
Veins	Constriction (α_1, β_1)	None

Actions of ANS

Structure	Sympathetic Effects	Parasympathetic Effects (muscarinic)
Heart	Increased heart rate, force of contraction, and blood pressure (β_1, β_2)	Decreased heart rate, force of contraction, and blood pressure



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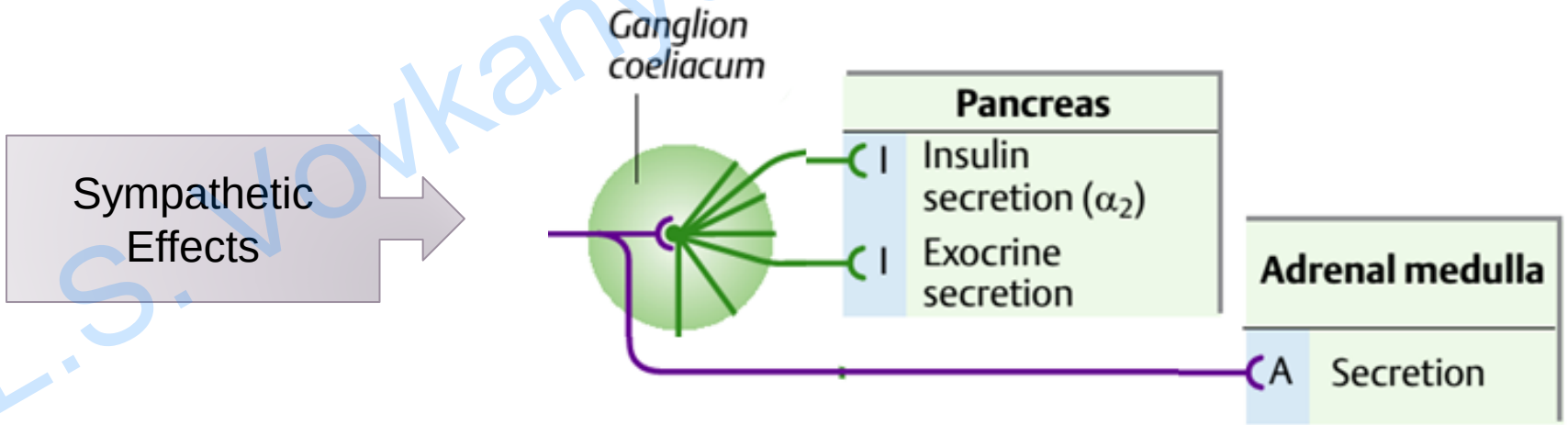
Actions of ANS

Structure	Sympathetic Effects	Parasympathetic Effects (muscarinic)
ENDOCRINE SYSTEM		
Suprarenal gland	Secretion of epinephrine, norepinephrine by suprarenal medulla	None (not innervated)
Pancreas	Decreased insulin secretion (α_2)	None



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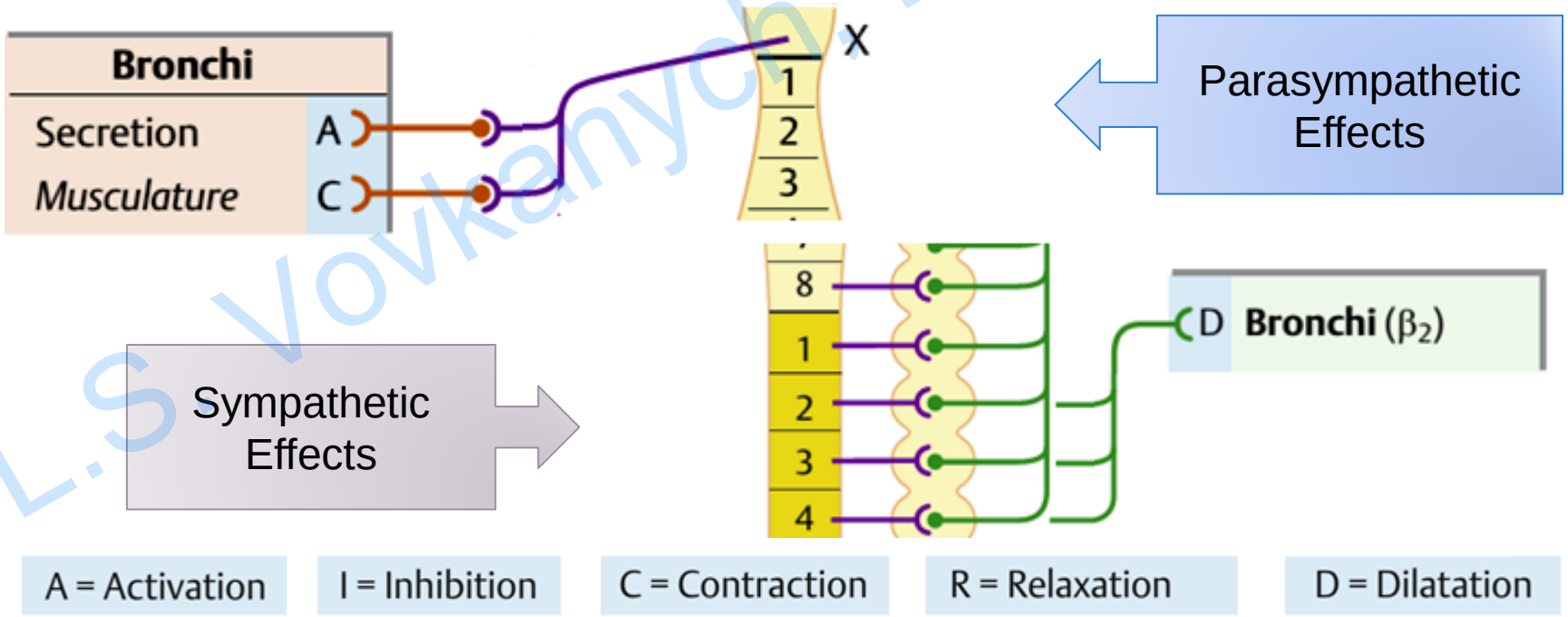
Actions of ANS

Structure	Sympathetic Effects	Parasympathetic Effects (muscarinic)
RESPIRATORY SYSTEM		
Airways	Increased airway diameter (β_2)	Decreased airway diameter
Secretory glands	Mucous secretion (α_1)	None



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Actions of ANS

Structure	Sympathetic Effects	Parasympathetic Effects (muscarinic)
DIGESTIVE SYSTEM		
Salivary glands	Production of viscous secretion (α_1, β_1) containing mucins and enzymes	Production of copious, watery secretion
Sphincters	Constriction (α_1)	Dilation
General **level of activity**	Decreased (α_2, β_2)	Increased
Secretory **glands**	Inhibition (α_2)	Stimulation
Liver	Glycogen breakdown, glucose synthesis and release (α_1, β_2)	Glycogen synthesis
Pancreas	Decreased exocrine secretion (α_1)	Increased exocrine secretion

Actions of ANS

Structure	Sympathetic Effects	Parasympathetic Effects (muscarinic)
SKELETAL MUSCLES	Increased force of contraction, glycogen breakdown (β_2) Facilitation of ACh release at neuromuscular junction (α_2)	None (not innervated)
ADIPOSE TISSUE	Lipolysis, fatty acid release (α_1, β_1, β_3)	???
URINARY SYSTEM		
Kidneys	Secretion of renin (β_1)	???
Urinary bladder	Constriction of internal sphincter; relaxation of urinary bladder (α_1, β_2)	Tensing of urinary bladder, relaxation of internal sphincter to eliminate urine

ANS Response to Muscle Activity

Sympathetic Division increases in many ways the ability of the body to perform vigorous muscle activity:

- Increased **arterial pressure**
- Increased **blood flow** to active muscles with decreased blood flow to organs, that are not needed for rapid motor activity (gastrointestinal tract and the kidneys)
- Increased **rates of cellular metabolism** throughout the body
- Increased **blood glucose** concentration
- Increased **glycolysis** in the liver and in muscle
- Increased **muscle strength**
- Increased **mental activity**

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